25TH ANNIVERSARY OF THE WIRELESS SECTION

ABSTRACTS OF ADDRESSES AT THE COMMEMORATIVE MEETING

INTRODUCTORY ADDRESS

By Colonel Sir A. Stanley Angwin, D.S.O., M.C., T.D., B.Sc.(Eng.), President.

The Wireless Section, now celebrating its Silver Jubilee, was the first of the specialized Sections of The Institution of Electrical Engineers to be formed. The primary reason for its formation was to provide a forum for the presentation and discussion of papers dealing with wireless, and to recognize and meet the specialized requirements of engineers interested in wireless. It was particularly appropriate that these requirements should be met by this Institution by reason of its long association with communication, dating back to its foundation in 1871 as The Society of Telegraph Engineers.

The Wireless Section was inaugurated on the 17th February, 1919, with an initial membership of 219, its first Chairman being Dr. W. H. Eccles; its membership is now over 1 900. Its field of usefulness and activities is reflected, not only by its growth in members, but also by the wide range of subjects that have been dealt with in its proceedings. A catalogue of the papers presented would indeed give an index of the progress and development of wireless during the past 25 years. The high standard of the publications of the Wireless Section has been achieved and sustained by the very representative character of the Section Committees and their Chairmen over the whole period of its existence.

It may be noted that the inauguration of the Wireless Section occurred at a time when the hard thermionic valve had been brought to a high stage of perfection in small sizes and a new era in wireless technique had commenced. Wireless telephony over short distances using medium waves was an accomplished practice, and one or two experiments had been made in telephony transmission over longer distances. The early years of this period saw the initiation and widespread development of broadcasting throughout the more advanced countries of the world. The application of valve technique to long- and medium-wave telegraph transmitting stations of progressively higher power continued, this expansion being materially assisted by the invention of the cooled-anode valve. Another useful invention which appeared about this time was the cathode-ray tube, which immediately proved to be an invaluable tool in investigating the performance of circuits and apparatus.

The middle years of the period were conspicuous for the development of short-wave communication, with world-wide telephony becoming a practicable possibility. A new period of expansion began and was still in progress when the present war broke out.

Two important advances which have come into prominence during the latter part of the past 25 years merit special mention.

The first is television, in the evolution of which British technicians have played a worthy part, and which has been prominent in the interests of the Wireless Section. The opening of the world's first public high-definition broadcast television service on the 2nd November, 1936, gave this country a lead which has not been eclipsed elsewhere. The possibilities which lie before this new branch of wireless, of which only the fringe has yet been explored, would themselves almost justify the formation of a specialized Section of The Institution.

The final development in this latter period has been the use of radio for the determination of the direction and distance of conducting or semi-conducting bodies by observation of radio-echo effects. Much of the earlier and now well-known methods of frequency-change and group-retardation or pulse transmission have been applied in this direction. The first application of this technique was in determining the heights of upper conducting layers in the atmosphere, and great pioneer work was done by British workers. The subsequent applications of this technique to aerial warfare and to other developments of radio for war purposes cannot yet be revealed. It is to be hoped that the time is not far distant when details of these applications may be made available for the arts of peace.

Whilst one cannot but deprecate that it should require the disaster of world war to give the maximum stimulation to wireless development, let us at least hope that modern applications can be directed to the common good and particularly to the preservation of life rather than to its destruction.

In such applications and in the further developments of wireless, I feel sure the Wireless Section of The Institution of Electrical Engineers can continue to play the great part it has consistently played during the past 25 years.

AN HISTORICAL SURVEY OF WIRELESS PROGRESS PRIOR TO THE INAUGURATION OF THE WIRELESS SECTION IN 1919

By W. H. Eccles, D.Sc., F.R.S., Past-President.

My purpose in this short address is to sketch the technical events that led to the founding of the Wireless Section a quarter of a century ago.

Just before the war of 1914–18, the transmitting plant used in workaday wireless was very varied in character. The largest stations in all countries were equipped with spark dischargers; in some the spark lasted only a short time, and in others it was formed between cooled electrodes of large area so that it was quickly quenched. Using hundreds of horse-power these stations communicated rather erratically across distances of three thousand miles. Other large stations used continuous waves. In Germany high-frequency alternators were most favoured; one form generated at, say, 12 000 c/s and fed the energy through iron frequency-multipliers on its way to the antenna. Another form, called a "reflection alternator," served as its own frequency multiplier. Both types virtually employed a suitably tuned circuit to draw out a harmonic.

In Denmark and the United States the arc was favoured; it was progressively made larger and larger, and in 1914 had reached an input of 200 kW. A large arc of 100-kW rating was

erected at the naval station of Horsea Island, while smaller arcs were frequently installed on naval vessels. Sometimes, in still smaller stations, harmonics of the fundamental frequency of an arc were utilized; and again harmonics of h.f. alternators were obtained by feeding the fundamental current through rectifying diodes.

At the receiving end, the variety of apparatus was even greater than at the sending end. In 1913, on merchant ships, the magnetic detector still lingered. The gassy diode was used at some fixed stations. The electrolytic detector was esteemed for its sensitiveness; but the favourite was the crystal contact rectifier, which survived into the broadcasting age together with the cat's whisker. Sometimes the audion was used to detect, sometimes to amplify the audio currents from a crystal rectifier. Direct aural methods, both thermal and electrodynamic, were also developed. All these methods were used on spark signals.

For arc signals, various forms of interrupted contacts or tickers were employed. One of the German transatlantic alternator stations used the tone wheel, a commutator-like device which made nearly as many contacts per second as the frequency of the incoming waves, to provide an audio current.

But, in 1913, there appeared in America a new variety of the heterodyne method of receiving continuous waves. This utilized local oscillations generated by a small arc, which were led with the signal oscillations to a crystal contact rectifier; the local frequency was chosen to make the difference frequency an audible one. This process achieved an unexplained amplification of continuous wave signals. Up to this time the arc and alternator had not given as good signals as the quenched spark—now all was changed, and the new signals excelled spark signals considerably at extreme ranges. In Russia, this heterodyne method was practised in a curious way; the fact that a crystal rectifier can be arranged to produce oscillations in an inductance-capacitance circuit—which was first demonstrated in London—was utilized at the receiving station; and this method was carried into the war period. Thus in one way or another continuous waves sprang into universal favour.

Yet this triumph of the primitive heterodyne was but a step to even greater things, for in 1913 the triode started its overwhelming advance into wireless. In the twelve months before the war began, the triode proved itself capable of amplifying high frequencies as well as low frequencies, generating oscillations by back coupling the output circuit to the input, amplifying and heterodyning simultaneously, and creating harmonics and modulating oscillations fed into it, as well as rectifying such oscillations. No new principle was introduced—the principle of accelerating and decelerating electrons by applying voltage to grids through which the electrons passed had been used by German physicists ten years earlier in abstract researches. Of the triode, I venture to say that never before in the history of applied science have so many valuable qualities been embodied in a single component.

During the last war the triode was intensely developed; it was made larger and became more reliable in operation. Around it were woven many inventions, such as cascade amplifiers, trigger relays, multi-vibrators, push-pull amplifiers and generators, the control of frequency by tuning fork and quartz, superheterodyne and super-regenerative receivers, the complete command of modulation, and hence telephony with the potentiality of broadcasting.

Consequently, at the end of the last war a great accumulation of theory and practice called for publication and discussion. In answer to that call this Section of The Institution was formed. When the Chairman of the Section gave his Address in 1920, there were present on the platform Graham Bell, the inventor of the telephone, and Oliver Lodge, the rival of Hertz in the search for electromagnetic waves. Apart from the honour of their presence, the view expressed by these great men that the Section was the advance guard of the British electrical world, was notable and true. For, when we look back on what has been accomplished by the triode and its derivatives in the past 25 years, we see that the foundation of the Section was but a recognition of a development of fundamental importance to the evolution of man's control over the forces of Nature, namely the harnessing of the electron.

PRINCIPLES AND THEORY, WITH PARTICULAR REFERENCE TO THE PROPERTIES OF THE IONOSPHERE

By Professor G. W. O. Howe, D.Sc., Member.

It is but natural that we should look back and survey the changes that have taken place during the last 25 years. This applies especially to those of us who were concerned with wireless telegraphy at the time of the establishment of this, the first specialized Section of The Institution.

The most outstanding achievements in the early days of wireless telegraphy were accomplished in spite of principles and theory. It is only 55 years since Hertz wrote, in reply to an enquiry from Huber, that there was no prospect of his discovery being used for telephony as the wavelength would be about 300 km. "If," he said, "you could construct a mirror as large as a continent you might succeed with such experiments." Hertz died 50 years ago, without knowing that he had laid the foundations of a new and revolutionary branch of electrical communication, although Crooks in 1892 had clearly recognized the implications of his discovery.

Many of the most outstanding advances in wireless telegraphy have been made, not along lines indicated by a study of principles and theory, but rather contrary to such indications, and the success achieved then led to a revision of the principles and theory. Prof. Ayrton once said that the reason why Marconi, and not Lodge, was the first to transmit radio signals across the English Channel was that Lodge was so well versed in electromagnetic theory that he knew that it was impossible, whereas Marconi, not knowing that it was impossible, went and did it.

The principles and theory of the time were all against him, but fortunately he made the experiment and gave those versed in the principles and theory the task of adjusting them to explain the facts, a task commenced by Heaviside and Kennelly in 1902 and carried on ever since by a number of scientists, with wonderful results.

In the 'eighties Balfour Stewart had suggested the existence of a conducting layer in the upper atmosphere as a cause of fluctuations in terrestrial magnetism, but until the discovery of the electron and ionization, such a suggestion could be little more than a vague idea. In his "Elementary Manual of Radio-Telegraphy and Telephony," Fleming in 1908 mentioned ionization of the atmosphere only to explain the absorption of the waves and the variation of such absorption during the 24 hours. He considered that air exposed to sunshine, although it may be extremely transparent to light waves, acts as if it were a slightly turbid medium for long electric waves, and advanced this explanation as an alternative to Marconi's suggestion that the

variations were due to the dissipative effect of sunlight falling upon the transmitting aerial. In further remarks Fleming acknowledged that the existence of the Heaviside layer had been suggested, but he seemed to favour other alternatives to explain the bending of the electromagnetic waves.

Ten years elapsed after Heaviside's suggestion before any appreciable progress was made in the principles and theory of the ionosphere. Apparently the first clue to the real nature of the mechanism by which the waves are refracted was provided by Dr. Eccles in 1912 and 1913. His hypothesis was based on the assumption "that the sun's rays ionize the atmosphere in such a way that the concentration of ions increases gradually as we ascend in the atmosphere. In this event a ray started horizontally will pursue a curved path with its concavity towards the earth, and thus, if the ionization is great enough, an electric ray may follow and overtake the curvature of the earth." In his calculations he assumed that the decrease of apparent permittivity was due to the movements of ions of molecular size.

The war then intervened and little more progress was made until 1924, when Larmor's paper, "Why Wireless Electric Rays can bend round the Earth," appeared. His thesis based on work at Cambridge was an extension and development of Eccles's theory, but taking the electron, and not the molecular ion, as the operative agent in the reduction of permittivity. Things now began to move more rapidly. Although in September, 1925, Smith-Rose and Barfield, in connection with their direction-finding researches, believed that "adequate experimental evidence of the existence of the Heaviside layer is still lacking," in the following month Appleton and Barnett showed from an experimental examination of the phenomenon of fading that it was due to waves deviated through large angles by the upper atmosphere, and that the waves were elliptically polarized in accordance with the magneto-ionic theory; they also concluded that there must be at least 100 000 electrons per cm^3 in the ionized layer. In the following year the same two workers showed, by experiments in which the transmitted wavelength was rapidly changed and the interference fringes photographed, that the height of the layer increased during the night and decreased rapidly about sunrise.

Notwithstanding this, in 1927 Banneitz, after describing what he calls the Eccles hypothesis, says: "It is very probable that these theories will one day be replaced by others that will prove more suitable for explaining the transmission phenomena." Thus seventeen years ago, some doubted the existence of the ionosphere, while others were exploring it and even determining the density of its population. On the other hand Prof. Pedersen, also in 1927, could see no reason for assuming the existence of *several* independent layers. The features in connection with the propagation of radio waves might be explained, he thought, in a fully satisfactory manner on the basis of the ionization of one single coherent portion of the atmosphere. His doubts were echoed in an editorial which appeared in 1931 in the *Wireless Engineer*. But the powerful experimental method, first devised by Brest and Tuve and used with such brilliant results by Sir Edward Appleton and other workers, definitely established the presence of more than one ionized layer.

The knowledge that we now have of the constitution and properties of the ionosphere represents a triumph of combined operations between experimental research and principles and theory.

THE EARLY DEVELOPMENT OF WIRELESS TELEGRAPHY IN THE NAVY

By ADMIRAL SIR CHARLES E. KENNEDY-PURVIS, K.C.B., R.N., Member.

The Navy's first contact with wireless telegraphy was through the inventiveness of Captain H. B. Jackson, R.N., followed almost immediately by that of Marconi. These two had been working independently on parallel lines. In 1899 a few ships were fitted with a single Hertzian oscillator energized by an induction coil. Trials were carried out under the direction of Marconi, and transmission over about 50 miles was obtained. By the end of 1900, 43 ships and eight shore stations were fitted with Marconi sets using the first tuned circuits on wavelengths of 395 ft and 1 150 ft. In 1905 the Navy started an experimental station on board H.M.S. Vernon, and H. A. Madge was our first civilian wireless expert. From then on the Navy developed wireless communication along its own lines. Its requirements in the early days were very similar to what they are now. Briefly, these requirements were maximum range, selectivity, ability to receive through atmospherics, and ability to transmit and receive at the same time on board ship on as many wavelengths as required. In those days we floundered about trying the most fantastic things to get more range and better reception. On the transmitting side, we ran through the stage of forcing up the power of spark sets, with all the troubles of finding condensers and other material which would stand up to the power and voltages we wanted to use. On the receiving side the coherer gave way to the Marconi magnetic detector, a simple and most effective instrument for those days. Then came the era of crystal detectors, electrolytic detectors, and, most important of all, Fleming's valve. Our main trouble was that without the ability to amplify we had no margin whatever to work on.

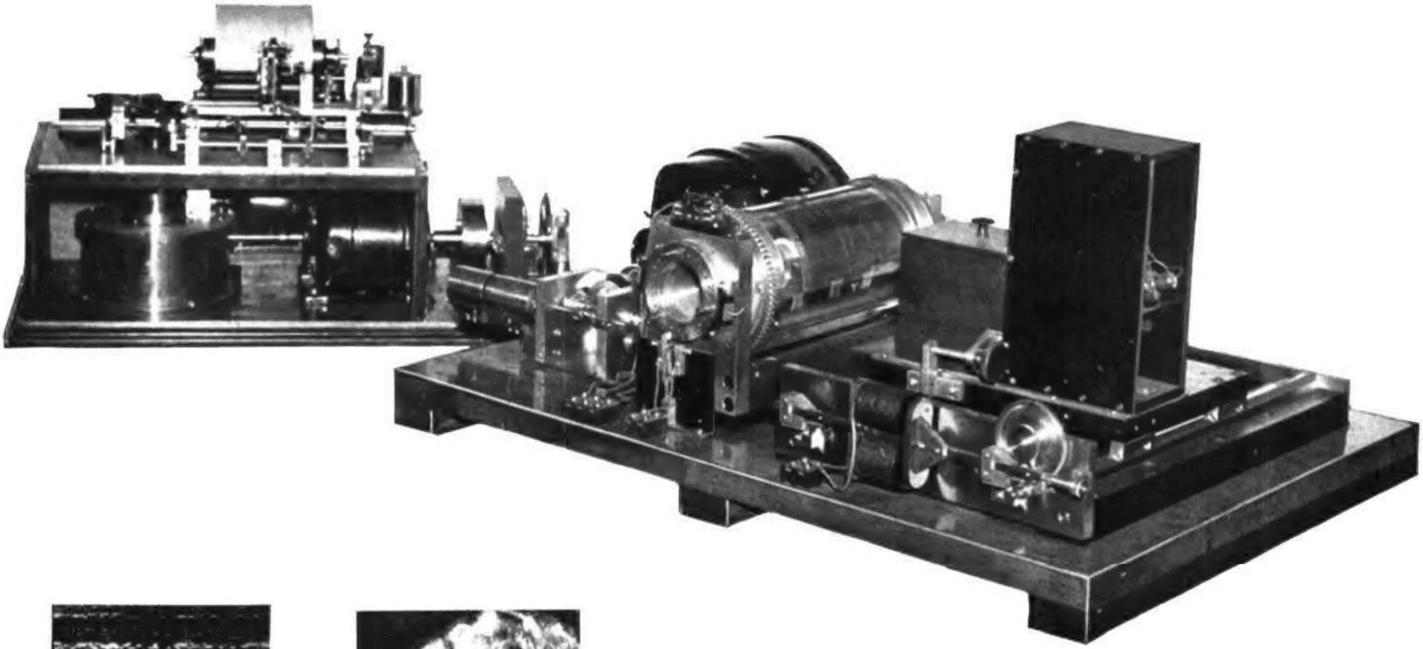
The old spark transmitter lasted right through the last war. Much energy had been put into developing the quenched spark for high power, but it did not meet our needs owing to its jamming properties, and it was soon overpowered by the Poulsen arc which opened up the whole field of continuous wave. The Navy was the greatest user of the arc and with considerable success developed its own designs suitable for ship use. The weak point in the early use of the continuous wave was, for a short time, the difficulty of reception. The valve was in embryo as a generator. The earliest method used was a ticker working with a crystal. Then came the heterodyne principle, but, owing to the lack of knowledge of valves, the early c.w. receiving circuits were fed by a small and very smelly enclosed arc stowed under the operator's table, which had a habit of going out at inconvenient moments and making loud popping noises. This period did not last very long, as the valve was beginning to come into its own.

The Poulsen arc, in conjunction with the crude receiving gear we then had, much increased our powers of communication during the first years of the last war, but the valve revolutionized everything. There was a continuous fight as to whether it was best to amplify, even if one could, the original signal before rectification, or whether one should devote one's energies to amplifying the audible note with all its disadvantages.

The use of the valve for transmitting developed from the wartime demand for low-power sets for inter-communication inside the Fleet which would not interfere with main reception. From these small beginnings, the Navy developed its own valve transmitters and the silica valve which it still uses.

In parallel with ordinary radiocommunication was the development of radio direction-finding afloat. It was not till well into the last war that we were able to operate direction-finding signals at all accurately. The adaptation to ships of the Bellini–Tosi system and the revolving-loop system was most difficult

Plate 1



RADIO FACSIMILE TELEGRAPHY

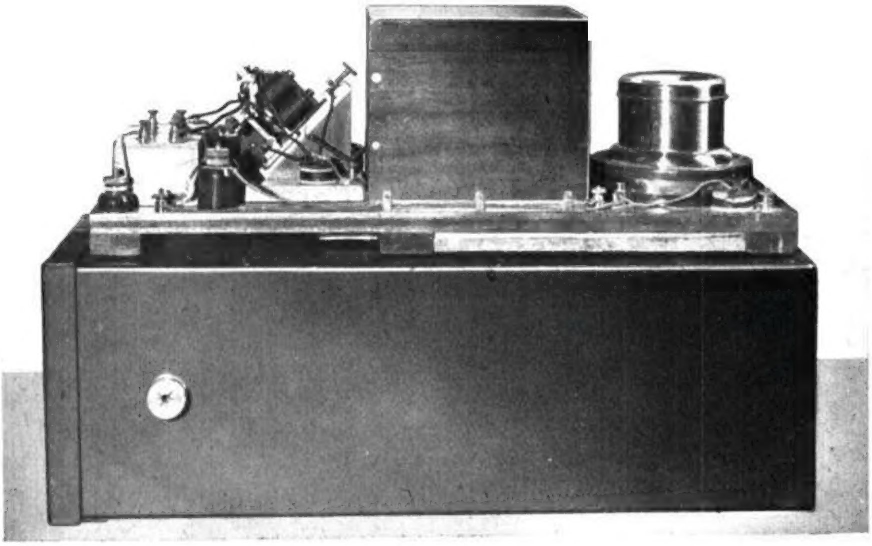
The apparatus shown at the top of the page was used in November, 1924, for transmitting photographs between England and America, the above photograph of the late Mr. R. A. Chattock, Past-President of The Institution, being one of the first transmitted.

The apparatus on the right is a modern "Transceiver" with which the photograph of the lady was transmitted from Stockholm and received in London in August, 1943.

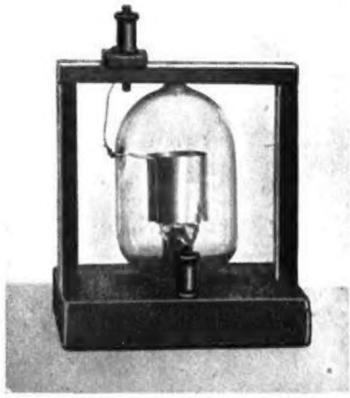
EXHIBITS AT THE COMMEMORATIVE MEETING

(*Facing page* 102)

Plate 2

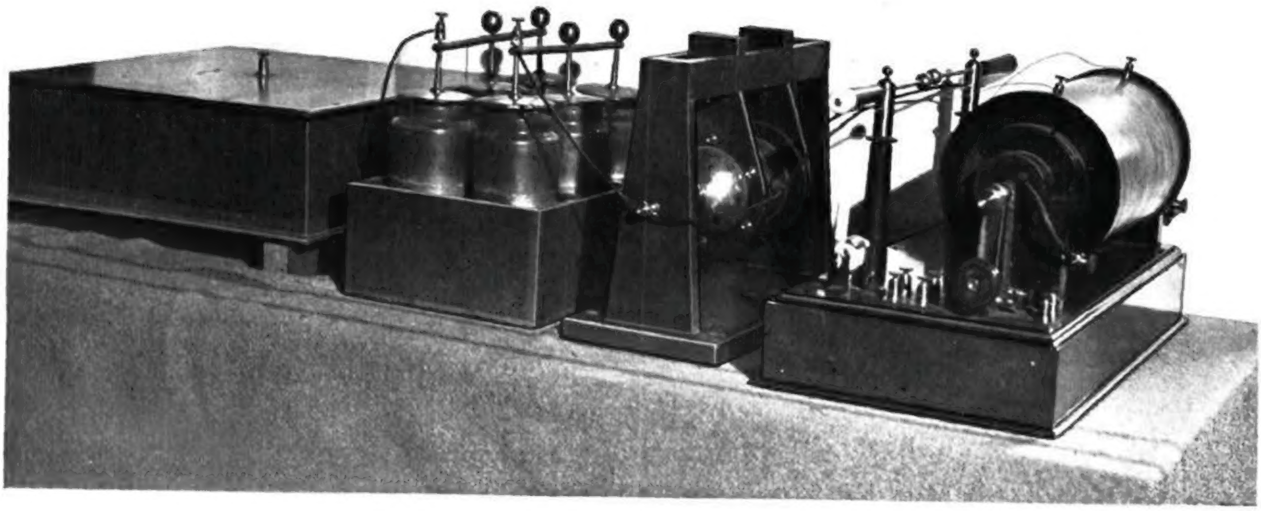


MARCONI'S COHERER RECEIVER (1900)
Similar to that used in the original Newfoundland transmission



ONE OF THE ORIGINAL FLEMING VALVES

(From the collection of Mr. R. M. Weston.)



ORIGINAL MARCONI TRANSMITTER (1900)
The power was supplied from a 10 in induction coil. Wavelength—about 300 metres

EXHIBITS AT THE COMMEMORATIVE MEETING

with the very limited knowledge available at the time. Again, the valve came to the rescue and solved many of the problems.

After the war, the opportunity came to take stock and start afresh, to develop valves and circuits and generally lay the foundation for the next stage, co-operating in full measure with other Departments and using the experience of the country as a whole.

About 1923 came the revolutionary introduction of short waves, with their well-known peculiarities. As the higher frequencies proved their usefulness, it was discovered how to mitigate their peculiarities. We can now get our range; we have selectivity which we never dreamt of; we can operate any number of channels; and we can work transmitters and receivers at the same time in the confined space of a ship.

The problem we always have in the Navy is the careful designing of all apparatus to withstand action conditions—one's own gunfire, enemy gunfire, and shock from explosions generally. The wireless gear in the Navy has stood up with the utmost reliability in action.

Before closing, looking back over these 40 years, I wish to express the Navy's gratitude to all those who have worked with us and who have helped us. The close co-operation between the Navy and the General Post Office has from the beginning been a characteristic feature in our wireless progress.

A SHORT REVIEW OF BROADCASTING DEVELOPMENT

By H. Bishop, C.B.E, B.Sc.(Eng.), Member.

The life of the Wireless Section has been the life of practical wireless telephony. The year 1919 saw the early experiments in speech and music transmission at Chelmsford and later at Writtle and other places, following which a 1-kW experimental transmitter was erected in Marconi House, London, and was used from the 14th November, 1922, for the first daily broadcasting service in this country.

Since those early days the correct acoustical design of studios and improvements in microphone response and in the associated low-frequency equipment have gone hand in hand with a scientifically-evolved distribution scheme to provide good reception of alternative programmes over practically the whole country. The transmission of high-quality speech and music over a land-line system designed primarily for commercial communication has raised many interesting problems in which the B.B.C. has always had the advice and co-operation of the engineers of the Post Office, whose commercial circuits have been adapted for this work.

Progress has perhaps been most marked in the design of transmitting stations. In the early days the transmitters in use did not exceed 1 kW in power and they worked in the 300 to 500 metre band. With the insensitive receivers available, each transmitter could be heard up to a radius of about 25 miles. The allocation by the International Broadcasting Union in 1925, of a limited number of wavelengths, on which the whole broadcasting service to Great Britain and Northern Ireland and overseas had to be planned and operated, called for a higher transmitter power than the few kilowatts then employed. In the same year the first high-power long-wave broadcasting station in the world to give regular programmes was built at Daventry. In the succeeding years, the power of transmitters increased very considerably, and modern transmitters have a radiated power of 200 kW or more, giving a primary broadcasting service over as large an area as the limitations of direct-ray reception will allow.

The recent increase in the power of transmitters has been made possible by the development of high-power valves, although many other problems also have had to be solved, such as an improvement in the efficiency of the transmitter and the means of obtaining power at the high d.c. voltage required. In the early transmitters using high-power anode modulation with Class A modulators, the ratio of power input to power radiated was about 4·6 : 1. The ratio for a modern Class B modulated transmitter is about 3 : 1. This has meant a considerable reduction in the size of power plant and switchgear and a substantial saving in operating costs for a given radiated power. With regard to the second point, the anode voltage required for a large water-cooled valve may be as high as 15 kV. Some years ago the only reliable convertors were the thermionic rectifier and the motor-generator, with efficiencies of about 84%, but in the search for improvement these have had to take second place to the hot-cathode mercury-vapour rectifier and the steel-tank mercury-arc rectifier, with efficiencies exceeding 95%.

In late years a notable advance has been made in short-wave broadcasting. The B.B.C. began its Empire service in 1932 with two 15-kW transmitters, following five years of experimental transmissions from a 25-m transmitter at Chelmsford. Both the number and power of transmitters have been progressively increased, and by the use of directional arrays there is now in operation a broadcasting service from this country which, although not wholly free from fading or interference, can be heard for several hours of the day with at least 90% intelligibility throughout the world.

The needs of the short-wave service have been one of the reasons for the steady improvements in methods of direct recording. The B.B.C. uses three systems, magnetic recording on steel tape, mechanical recording by cutting the opaque surface of a gelatine film on a celluloid base, leaving a transparent track, and mechanical recording on various forms of cellulose-coated discs. All these methods are capable of direct play-back, but because of its other advantages the disc system is the most used.

It is nowadays necessary to secure high frequency-stability in transmitters. With modern equipment it is a simple matter to realize this to a few parts in a hundred million with crystal equipment which does not require elaborate installation or operational procedure. For the control of short-wave transmitters, which are usually required to change their frequencies several times a day, variable-frequency drives, having a resetting accuracy of at least $\pm$ 50 parts in 10^6, and a short-term frequency stability of better than $\pm$ 5 parts in 10^6, have been found more convenient than crystal oscillators, whose lack of flexibility is a serious disadvantage.

Finally, mention must be made of television. No single individual can claim credit for the process, which owes much to many different inventors, some of whom were working 60 and more years ago. The B.B.C. started experimental low-definition television programmes in 1929, which continued until 1935; but it had long been realized that this sytem had no future, because of the poor quality of the pictures transmitted. A new service of high-definition television was started in 1936, but the war caused the suspension of the service just as it was getting into its stride. This interruption was much to be regretted because of the great technical development that had been made in the period of nearly three years during which a regular service had been running. In television, this country held a decisive lead over all others, including America, and the extensions and technical improvements that were contemplated would have increased that lead.

FUTURE POSSIBILITIES OF WIRELESS*

By R. L. SMITH-ROSE, D.Sc., Ph.D., Member.

A review of the future possibilities of radio technique is difficult, as security reasons preclude my utilizing a knowledge of the present state of the art to anticipate many of the attractive applications which are likely to take place in the not too remote future. Yet it seems certain that in the field of straightforward communication much of the recent success in the use of very high frequencies (above 100 Mc/s) will be applied to the establishment of radio telephone and telegraphic links over distances ranging up to 100 miles or so, particularly for relieving the congestion in the high-frequency bands (below 30 Mc/s) which are more suitable for longer-distance communication. For practical success in this sphere, the sources of these very high frequencies will require frequency control to at least the precision which prevails at lower frequencies, if the most economical use of the available frequency channels is to be attained.

The authority regulating the communications of the future will also have to decide which of the various modulation systems now being used, regardless of the channel space occupied, may be permitted to continue under more law-abiding conditions. In the lower-frequency bands, in which the radio waves are propagated through the ionosphere, the vast increase in our knowledge of ionospheric conditions obtained during the war years, will undoubtedly be reflected in the more economical distribution of frequencies to suit the various services and their operating distances, times and seasons. It is further expected that an international network of recording stations will be established to give the latest information on ionospheric conditions in all parts of the world.

The past four and a half years of war have been accompanied by revolutionary advances in the application of radio as an aid to aerial and marine navigation. The exigencies of the war have necessitated the finding of solutions to many problems in the straightforward location of the position of transmitting stations on all wavelengths; and the results of this work will clearly be applicable to ship and aircraft direction-finding for navigational purposes, assisted by special transmissions from appropriately placed beacons. It may also be anticipated that the various devices known before the war as "iceberg-detectors" and "collision preventers" will have reached the stage of being suitable for direct application to the navigation of civil craft, both in the air and at sea. War requirements will have provided an adequate supply of trained navigating personnel fully acquainted with the operation of these systems. The only remaining difficulties to be overcome would appear to be, first, the apparently inborn conservatism of those controlling large-scale civilian transport services, and secondly the allocation of responsibility for control and operation of the requisite beacons and other equipment, both on land and in the craft.

If the advances made in the science of radio detection have been accompanied by corresponding progress in the art of radio-operated remote control, it is no mere flight of fancy to look forward to the day when pilotless freight-carrying aircraft will fly distances comparable to that of the north-Atlantic route between the United Kingdom and North America. Such aircraft would fly along specially selected routes under the control of land operators on each side of the ocean; during flight the position of all craft would be continuously under the supervision of these operators. Radio-operated instruments installed in the aircraft could give information as to meteorological conditions along the route, for the benefit of traffic-operating services and the normal weather-forecasting establishments.

In the field of aural broadcasting, it is likely that the use of wider audio-frequency bands, whether for amplitude or frequency modulation, will be in greater demand to secure high-quality reproduction, and it is hoped that the experience gained by broadcast-receiver manufacturers in meeting the demands of military applications will facilitate the production of broadcast receivers suitable for the audio-frequency range required. The remarkable advances made recently in our knowledge of the possibilities of video-frequency modulation, amplification and detection will undoubtedly have an immediate effect upon the resuscitation of television broadcasting in this country; and we may look forward confidently to the widespread application of television, both for entertainment purposes and for continuously recording "outside" topical events. The collection of such outside material will be considerably facilitated by advances in radio-frequency cable technique, distortionless video-frequency amplifiers, very-short-wave radio links, and, last but by no means least, the existence of a large body of highly trained and specialized personnel suitable for all technical operating and manufacturing positions.

It is to be anticipated that much of the ground cleared before the war in the direction of controlling and suppressing man-made electrical interference will have to be covered again and the necessary legislation enacted, if we are to gain the maximum benefit from the application of advances in short-wave radio technique to civilian needs. There is furthermore a probable large field of progress awaiting development in the application of high-frequency heating methods to various manufacturing processes, ranging from metallurgy to the preservation of foods.

In conclusion, I should like to refer to the heavy debt which all the applications and advances that have been mentioned at this meeting owe to those patient investigators and research workers, who in recent years have laid the foundations and established the essential facts which form the basis of all this development work. It might be thought that with all the intensive effort that has been given to it in recent years, the field of radio research had been scoured to the bare rock, but such is not the case. The needs of military applications have brought to light many gaps in our previous knowledge, and the advances into wide new portions of the radio-frequency spectrum have necessitated a fresh attack on the properties of the corresponding waves, and of the means of generating and receiving them. Much of the work already done has had to be repeated in other portions of the spectrum, and many of the devices which can be produced under the stress of war, when cost is a secondary object, will require considerable attention and development if they are to find a successful application under the more economically regulated conditions prevailing in times of peace.

Finally, it may be noted that there are still several octaves now under practical development between the shortest radio waves and the longest infra-red waves. In short, therefore, the vista before us in the field of radio research and development is a combination of ground partially developed and cultivated and of a large area of virgin territory beyond, which is awaiting the pioneer efforts of the new generation of workers, who have had their first intensive training under the stress of war conditions.

* Recorded overseas and reproduced at the meeting.